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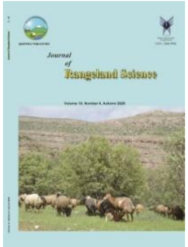

Research and Full Length Article:

The Effect of Optimum Management of Lands on Reducing the Peak Discharge and Water Turbidity (Case Study: Manshad Watershed, Yazd Province, Iran)

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Abstract. One of the main factors to decrease water quality in rivers is land use changes. This study was conducted to choose the best way for land use management in order to increase water quality related to the least turbidity, improving natural landscape quality and attracting ecotourism. So, the effect of land use changes on turbidity was investigated for 2 to 100-year periods using GIS and Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS) model in 2012, in Manshad watershed, Yazd province, Iran. The Curve Number **(**CN) and land use planning model were variables in each simulation stage. After preparing the CN map, HEC-HMS model was calibrated for the observed rainfall-runoff events using CN method, Soil Conservation Service (SCS) model and lag time searching process. Finally, the best model was chosen among linear and non-linear sediment rating curves. The results showed that there was a lot of conformity between present land use and land use planning model. Terrace removing in land use planning model (as a scenario) increased flood volume (6.11%), peak discharge (6.23%) and turbidity in the peak discharge (11.02%) compared to the current land use. Therefore, according to the results, garden terracing in allowable slopes helps to manage water and soil so that there was almost no difference between two scenarios in terms of water turbidity in Watershed. It means that this watershed is managed on the basis of optimum land use.

Key words: HEC-HMS model, Land use change, Optimum land use, Turbidity

Introduction

One of the most important water quality variables is the suspended sediment (turbidity). It is essential to know about its amount and changes to determine natural landscape quality and aquatic ecosystems. Water quality shows environmental management method and different environmental aspects to transfer sediment and pollution to rivers and lakes (Melesse and Shih, 2002; Mohamadi, 2016). One of the main factors to decrease water quality in rivers is land use changes. Land use type has the most effects on creating and accelerating erosion and sediment compared to the other factors (Fohrer *et al.*, 2002; Niehoff *et al.*, 2002; Talaei *et al.*, 2011). Changes in transferring sediment will lead to changes in other variables concentration of water quality. Suspended sediments cause to transfer soil nutrients which will increase turbidity. Increasing turbidity destroys the soil and water resources. So, it is better to optimize land use through evaluation and land use planning in order to select the most appropriate land management practices and control the suspended sediment into water (Petrosillo *et al.*, 2006).

There are several studies about evaluating the effects of land use on flood processes. Chappi (1997) studied the effect of land use type on the amount of erosion and sediment in Chehel Gazi watershed of winter dam in Iran. The results showed that dry lands on the steep slopes had more erosion and sediments than rangelands with medium to good conditions. Khalighi (2003) investigated the effects of land use changes using HEC-HMS model in Dozchay Baran watershed of West Azarbaijan in Iran and found that flood has increased 70% in some watershed divisions compared to the previous periods but this rise is lower in the peak discharge and higher return period. Zahedi *et al.* (2010) studied the effect of land use change on urban watershed hydrology in Ziarat watershed of Gorgan province in Iran and demonstrated that the height of current land use has increased 1.37% compared to previous land use due to land use change, forests degradation and uncontrolled construction, which results in flood increasing in the late years. Investigating scenarios showed that if construction and land use changes continue, floods will be more severe in the future. Akhzari *et al*. (2013) investigated land use management scenarios impact on water erosion risk in Kashidar watershed in Golestan province. Among 8 scenarios, most appropriate water erosion management that had minimum proportion of high water erosion hazard classes, maximum gross margin and minimum establishment cost was chosen as the best scenario.

Walling and Hedly (1984) declared that the rate of sediment production has increased 20% from forest to rangeland use and about 130% from rangeland to agricultural use due to the effect of improper land use change around Sydney in Australia. Kafle *et al.* (2007) studied the effect of rainfall on runoff production using HEC-HMS[1] model in a watershed in Vietnam. After the model calibration and simulation, the results indicated that simulated peak flood was very close to observational amounts. Wang *et al.* (2008) investigated different effects of land use in China and found that converting rangelands to forest leads to increase the amount of yearly runoff and ground water reduction because of decreasing soil permeability and transpiration.

Therefore, the purpose of this study was to compare turbidity between current land use and optimum land use scenarios using HEC-HMS rainfall-runoff simulation model in order to choose the best management practices of land use as a result of human intervention, turbidity reduction and improving the quality of landscapes and tourism.

[1]Hydrologic Engineering Center – Hydrologic Modeling System

Materials and Methods

Study area

Manshad watershed with an area over 6010 ha is located in 37 km of Mehriz in Yazd province of Iran at 31˚ 28′ 59″ to 31˚ 35′ 42″ northern latitude and 54˚ 09′ 56″ to 54˚ 16′ 16″ eastern longitude (Fig. 1). The average altitude is 2810 m above sea level. The average annual precipitation is 301 mm, the mean annual temperature is 11˚C and climate based on Domarten method is semi-arid. According to the amount of springs and aqueducts discharge (4.5 million m^3), this region with an area of 6.65 km^2 is under cultivation of horticultural and agricultural products and has water need given as approximately 7452149 m^3 per year; 2976527 m^3 is related to spring season. This area concludes rocky outcrops (47.48 km^2), agricultural lands and gardens (6.65 km^2), rangelands (5.59 km^2) and streams (0.32 km^2).

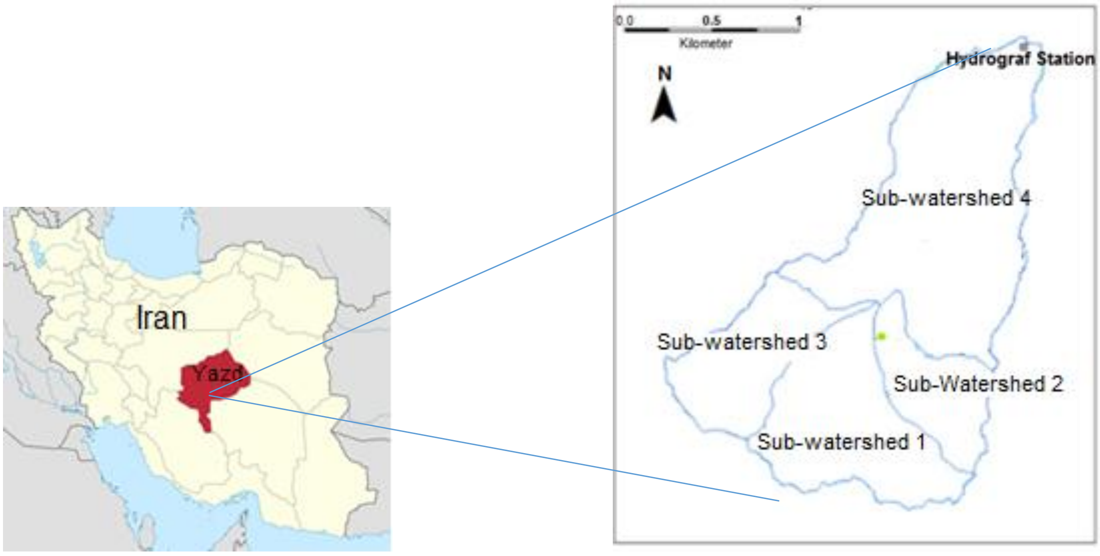

Fig. 1. Location of Manshad watershed in the Country

Methodology

First, the study area was determined using topographic maps (1:50000) and was divided into nine sub-watersheds based on the physiographic characteristics. Then, digitizing the watershed, sub-watersheds borders and hydrographic network was done in GIS. Physical properties of watershed and sub-watersheds were determined and the required based maps were provided. According to the HEC-HMS model and its inputs, certain parameters were used to perform the model.

In flood studies, some conditions were considered to predict the amount of flood in the future. These conditions can be the result of government decisions for economic, political, social, cultural development and so on. Planning certain conditions for the future is called scenario. In this study, two scenarios were designed: watershed current management and watershed suitable management (optimistic scenario). A new watershed model was created in the HEC-HMS rainfall-runoff model for each land use scenario and runoff hydrography was simulated for each scenario.

Land use optimal model (land use planning)

According to the following steps, ecological potential of Manshad watershed was evaluated using GIS and ARC GIS10 software on the basis of system analysis invented by Lan Mcharg (Makhdoom, 1999): overlaying elevation, slope (Fig. 2), aspect maps and creating land form unit map and then overlaying with soil, vegetation type and density for creating micro ecosystem unit map and finally preparing a table of micro ecosystem unit.

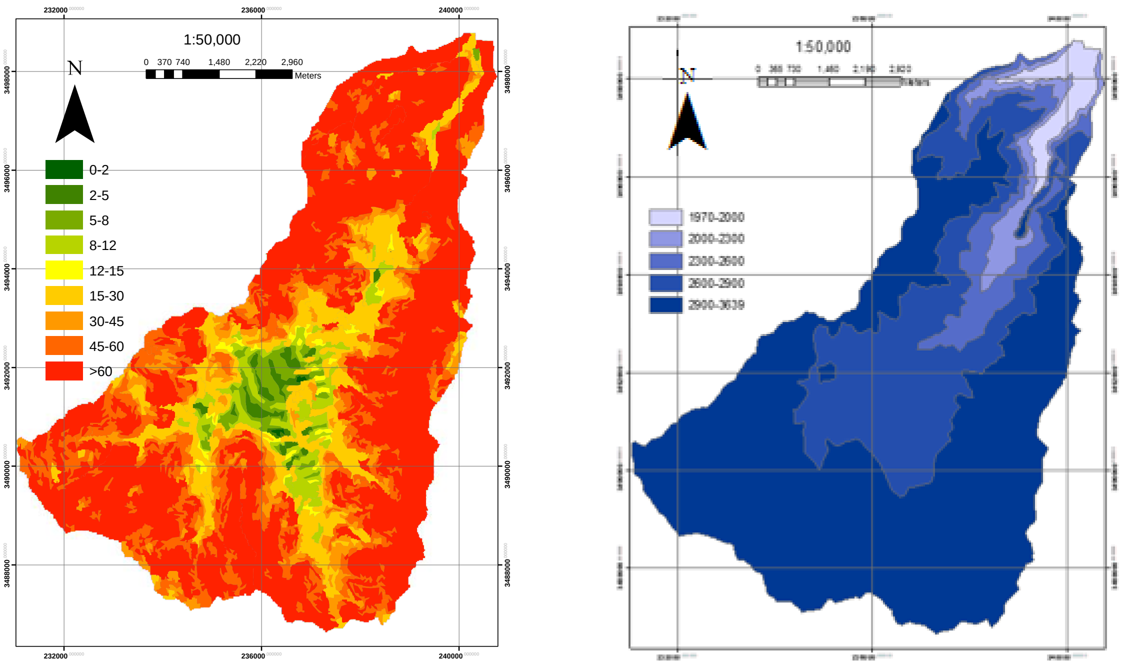

Fig. 2. Digital elevation model (DEM) (right) and Slope Analysis (Left)

Simulating peak discharge using HEC-HMS hydrologic model

The HEC-HMS hydrologic model was calibrated and validated against rainfall-runoff data using curve number (CN) (Soltani *et al.* 2010), SCS (Soil Conservation Service) unit hydrography in sub-watersheds and finding lag time process method in rivers network and was used to simulate peak discharge.

In order to take advantage of this model, it is also necessary to produce a curve number map for Land use optimal model (land use planning). So, scoring was done using Tables of determining curve number (Mahdavi, 2002) and the average of gained scores was defined as a curve number for each land use. Then, the curve number of weighted mean was calculated for each sub-watershed according to equation (1):

Eq. 1 $$CN = [\sum^{n} \frac{(Ai)}{100} * (CNi)]$$

Where CN is the weighted mean in sub watershed, Ai is an area percent of watershed curve number is CN. Yang *et al.* (2015) also used a GIS semi-distributed model to imply curve number technique and predicted accurate results for unique runoff characteristics.

Fitting sediment rating curve

60 pairs of discharge data (m^3/sec) and suspended sediment (mg/liter) were received from Yazd regional water organization. The data were fitted seasonally based on the linear, cursive (poly line) model and intermediate categories. Then, the appropriate model with the best predictive capability was selected on the basis of statistical indicators. Finally, data analysis was done in *SPSS17* and *EXCEL* software.

Results and Discussion

Land use planning model

After doing the related stages, micro ecosystems units and land use planning model were prepared for Manshad watershed (Fig. 3).

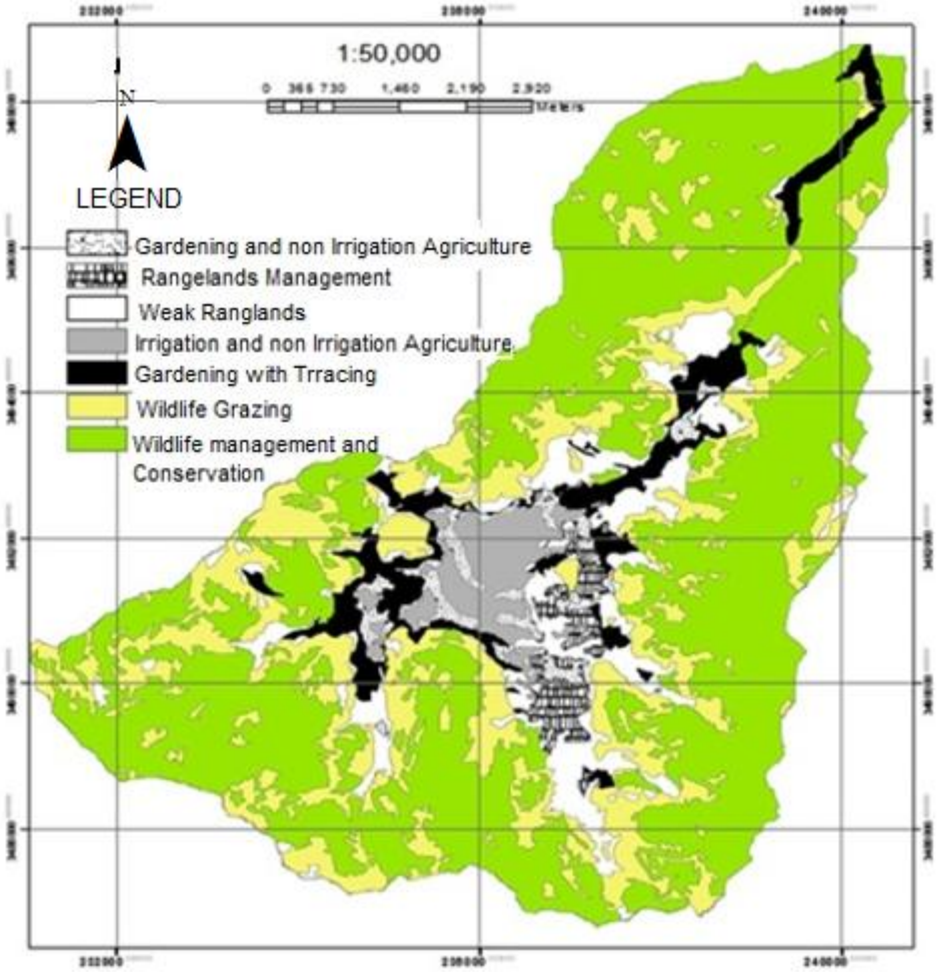

Fig. 3. Optimum Land use of Manshad Watershed

Comparing conformity percentage of land use planning preference and current land use

There is no land unsustainable use condition in the study area. Land use condition is sustainable in more than 95% of Manshad watershed places and current land uses are compatible with proposed optimized land uses. There is only a little change related to converting rangelands to terracing for gardening and farming on the slopes more than 30% but on 12% to 30% slopes, terracing was done according to the ecological, technical and economic aspects.

Curve Number

Terracing agricultural lands and gardens on the slopes 30% and less has caused to perform current land use like an optimized land use model. But according to the land use planning model, these terraces have exceeded allowable slopes for terracing and have caused the decreased weighted mean of curve number in the current land use as compared to it in land use planning scenario. Fig. 4 shows the curve number maps in current and optimum conditions. Based on the obtained maps, the rate of curve numbers in both scenarios is almost the same. This means that the Manshad watershed has been managed in logic conditions. Table 1 also illustrates the weighted mean of curve number for the two scenarios. Kar *et al.* (2015) also used curve number and percentage of impervious area in HEC -HMS model. They indicated strong coherence of unit hydrography model responses to the actual situation of historical storm runoff events.

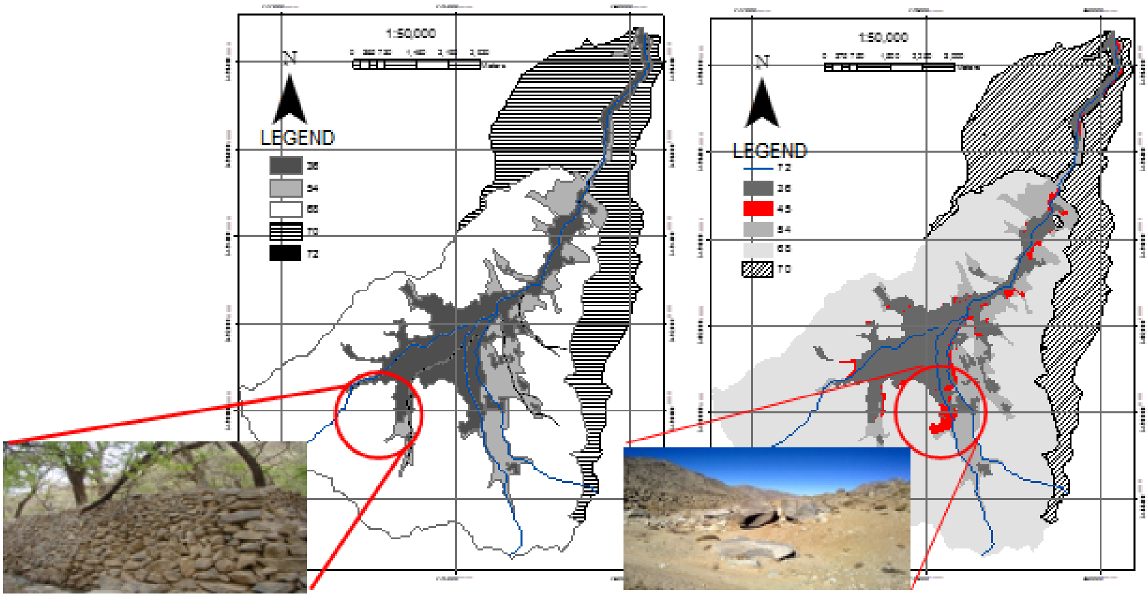

Fig. 4. Curve number of current land use (left) and Optimum land use (right) in Manshad watershed.

Table 1. Weighted mean of curve number for each sub-watersheds in land use scenarios

Parameter	Scenario	Sub-watershed				Weighted mean of curve number
		1	2	3	4	
Curve number	Current land use	62.3	62.5	64.5	64.5	63.71
	Land use planning model	62.7	62.5	64.6	64.7	63.82

HEC-HMS hydrologic model

HEC-HMS hydrologic model was used to evaluate the peak discharge in each scenario. Indices values of model efficiency in validation stage are presented in Table 2. Dastorani *et al.* (2011) tested the efficiency of the HEC-HMS model and indicated that this model has a good ability in rainfall-runoff simulation in not-gauged catchments. They also showed that curve number plays an important role in the accuracy of the results produced by this model.

Table 2. Indices values of model efficiency in validation stage.

Indices	Efficiency
Nash-Sutcliffe coefficient	0.75
Intensity Duration Frequency	0.028

Fitting sediment rating curve

According to the mean square error in each model, classes average with a power curve= $^{1.834}0.325\ Q_w\ Q_s$ were selected as the best sediment rating model (coefficient= 0.84, the mean square error of each model= 0.0304).

The results of dividing data into two categories based on ascending and descending branches led to achieve relationships with higher correlation coefficient. Coefficient is obtained 95% and 94% for each hydrography ascending and descending branches. State of data distribution like sediment rating is presented in Fig. 5.

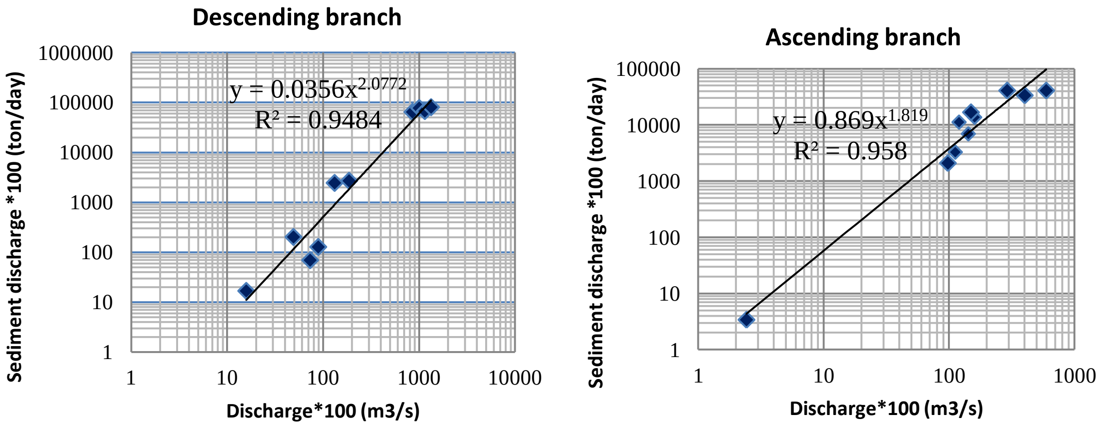

Fig. 5. sediment rating of ascending and descending branches with fitting data average in Manshad watershed (1997-2012).

Hydrography and sediment graph in current land use and land use planning model

The amount of suspended sediment was determined in the form of hydrography and sediment graphs in current land use and optimal land use scenarios by combining the results of fitting sediment rate and simulation of peak flow. Assuming that the peak of water turbidity and peak flow are at the same time, runoff and sediment graphs were predicted using simulation of the HEC model and sediment rate, respectively. Figs. 6 to 8 show the comparing of estimated hydrography and sediment graph for different return periods (2, 50 and 100 years) and land use scenarios in the study watershed output.

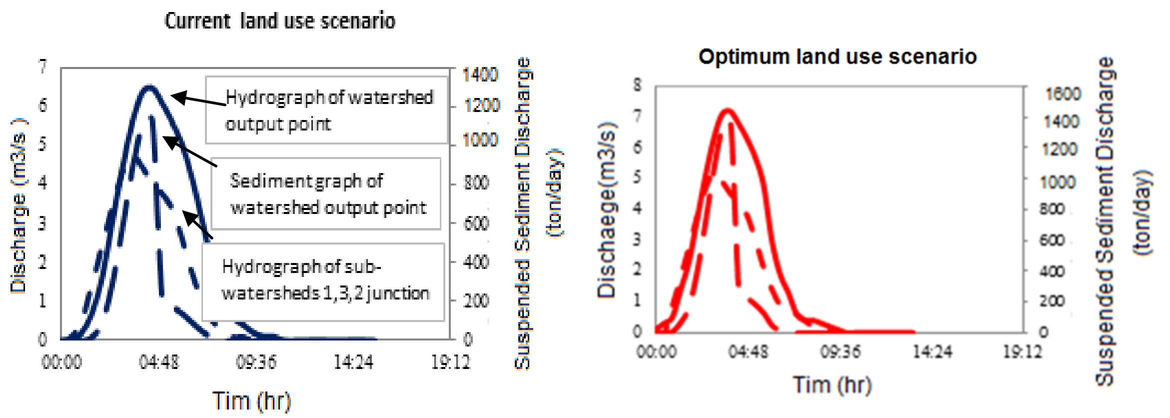

Fig. 6. Comparing estimated hydrograph and sediment graph for return period of 2 years and land use scenarios in Manshad watershed output.

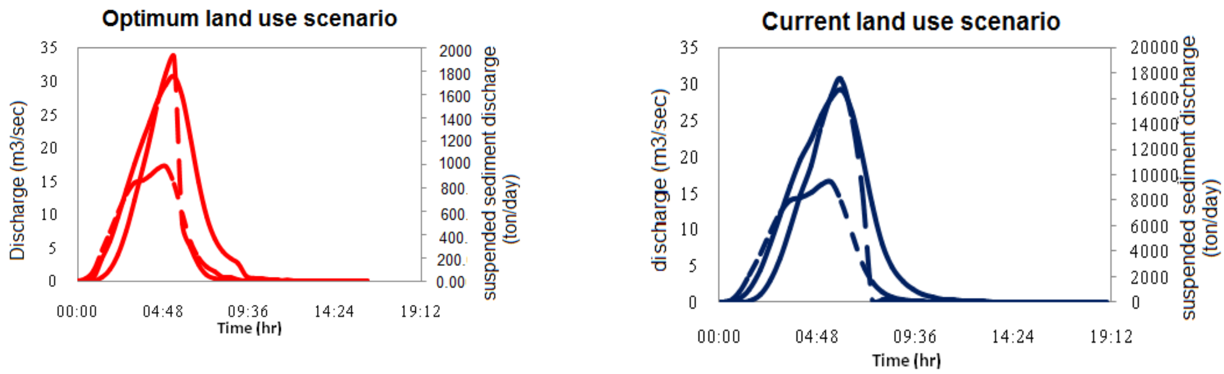

Fig. 7. Comparing estimated hydrograph and sediment graph for return period of 50 years and land use scenarios in Manshad watershed output.

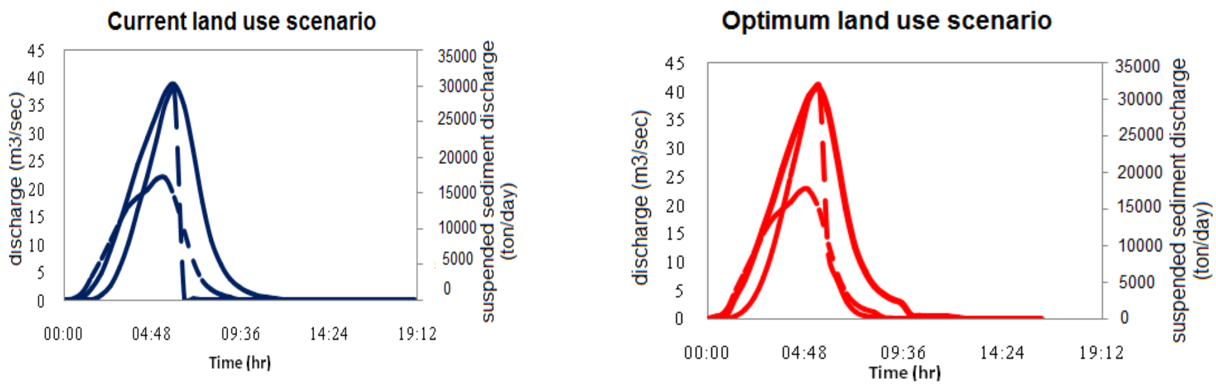

Fig. 8. Comparing estimated hydrograph and sediment graph for return period of 100 years and land use scenarios in Manshad watershed output.

The values of relative difference percent of output parameters between two scenarios in the simulation are presented in Table 3. According to the Table 3, the effect of land use type has decreased in high return periods and its effect is more sensible in low return periods.

The effect of land use type on peak discharge, flood volume and turbidity in the peak discharge for different return periods of rainfall has also been investigated. As it can be seen in Table 4, if this watershed is managed based on the optimum land use, peak discharge and turbidity have no significant differences for two scenarios. This means that lands in this watershed are completely managed based on the optimum land use.

Table 3. The values of relative difference percentage of output parameters between two scenarios in simulation.

Return period (Year)	Relative difference percentage		
	Peak discharge	Flood volume	Suspended sediment
2	9.72	8.10	16.97
5	6.60	7.67	13.18
10	6.56	7.14	11.62
25	5.21	5.38	9.27
50	4.88	4.29	8.70
100	4.43	4.08	7.91

Table 4. The effect of land use type on peak discharge, flood volume and turbidity in different return period of rainfall.

Return period (Year)	Optimized land use scenario			Current land use scenario		
	Turbidity (Mg/litr)	Flood volume (1000 m^3)	Peak discharge (M^3/s)	Turbidity (Mg/litr)	Flood volume (1000 m^3)	Peak discharge (M^3/s)
2	15848.7	111.1	7.2	13158.1	102.1	6.5
5	32580.3	170.7	10.6	28285.6	157.6	9.9
10	51074.1	232.3	13.7	45135.7	215.7	12.8
25	112040.7	350.9	21.1	101643.5	332	20
50	221620.9	466.2	30.7	202319.4	-	29.2
100	368480.8	600.1	40.6	339305.5	575.6	38.8

In hydrography simulation part, numerical values of peak discharge and flood volume in two defined scenarios can be trustworthy because efficiency coefficient values of applied model (for example the value 0.75 for Nash-Sutcliffe coefficient) in Manshad watershed showed acceptable simulation results and several studies such as Nikookar (2006), Shokouhi (2007), Roshani (2003) and Shieh (2007) confirm this. So, it is expected that the time of water turbidity peak has been predicted correctly to choose the best time for sediment traps activity. Variables coefficients in the equations represent transferring capability between hydrography ascending and descending branches. These results have been corresponded with the results of studies by Walling and Web (1982), Kothyari *et al.* (1996) and Sadeghi *et al.* (2006).

The effect of land use planning scenario (optimum management) can decrease the flood volume, the peak discharge and suspended sediment equal to 6.11%, 6.23% and 11.02%, respectively. The only problem in this watershed is soil deficiency. Farmers have the maximum use of minimum soil by terracing and creating agro-forestry system (because the study area is mountainous, soil is not salty and there are enough water resources). All these factors, dry weather condition and lack of tourism facilities caused farmers make a tourism place by terracing on the slopes (more than allowable slopes) and bring a capability for gardening. It is obvious that these terraces in allowable slopes (instead of terracing with a lot of costs) help soil and water management and there is not a great difference between the two scenarios from the view point of watershed output turbidity. These terraces can also be appropriate ways to perform land use planning projects.

Conclusion

In this research, we have investigated the effect of better land use management (optimum land use) on some hydrologic characteristics of the watershed (flood volume, peak discharge and suspended sediment). For doing that, CN map was provided for different scenarios and by entering the CN map, the Hec-Hms hydrologic model was run for each scenario. Based on the obtained results, the reduction of flood volume, peak discharge and suspended sediment in case of optimum land use is completely significant. Meanwhile, in this study area, there is no difference between the current and optimum land uses from hydrologic viewpoints. This means that farmers in this watershed have managed their lands based on the optimum land use.

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بررسی اثر مدل بهینه کاربری اراضی بر کاهش دبی حداکثر و گل‌آلودگی آب (مطالعه موردی: حوزه آبخیز منشاد استان یزد)

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چکیده. یکی از عوامل اصلی در کاهش کیفیت آب رودخانه‌ها، تغییر کاربری اراضی در سطح حوزه است. پژوهش حاضر با هدف انتخاب بهترین شیوه مدیریت کاربری اراضی به منظور افزایش کیفیت آب از نظر کمترین گل‌آلودگی، بهبود کیفیت مناظر طبیعی و تفرجگاهی انجام شد. بدین منظور آثار تغییر کاربری اراضی بر گل‌آلودگی برای دوره‌های بازگشت ۲ تا ۱۰۰ سال با تلفیق سیستم‌های اطلاعات جغرافیایی (GIS) و مدل HEC-HMS، در سال ۱۳۹۱ در حوزه آبخیز منشاد استان یزد بررسی شد. پارامتر متغیر در هر مرحله شبیه‌سازی، مقدار شماره منحنی (CN) و مدل آمایش سرزمین داده‌ها بود. پس از تهیه نقشه CN، مدلHEC-HMS با استفاده از روش شماره منحنی، معادله حفاظت خاک SCS در سطح زیرحوزه‌ها و نیز به روش روندیابی زمان تأخیر برای وقایع بارش-رواناب مشاهده‌ای واسنجی و اعتباریابی شد. در نهایت مناسب-ترین مدل از بین منحنی‌های سنجه رسوب خطی و غیرخطی برازش شد. نتایج نشان داد که درصد انطباق کاربری فعلی با مدل آمایش خیلی زیاد بوده و حذف تراس‌ها در مدل آمایش سرزمین در مقایسه با کاربری فعلی به طور متوسط ۶/۱۱ درصد به حجم سیل، ۶/۲۳ درصد به دبی اوج جریان، ۱۱/۰۲ درصد بر گل-آلودگی در دبی اوج جریان افزود. بنابراین با توجه به نتایج بدست آمده، تراس‌بندی باغات در شیب‌های مجاز به مدیریت آب و خاک حوزه آبخیز کمک زیادی کرده به طوریکه اختلاف زیادی در گل‌آلودگی خروجی حوزه بین دو سناریو دیده نشد.

کلمات کلیدی: مدل HEC-HMS، تغییر کاربری اراضی، کاربری بهینه، گل‌آلودگی